

# The Laser Cooling and Atomic Physics (LCAP) program at JPL

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**Abstract.** We present an overview of the Laser Cooling and Atomic Physics (LCAP) program, and of the role played by the Jet Propulsion Laboratory in developing the core technologies for this program.

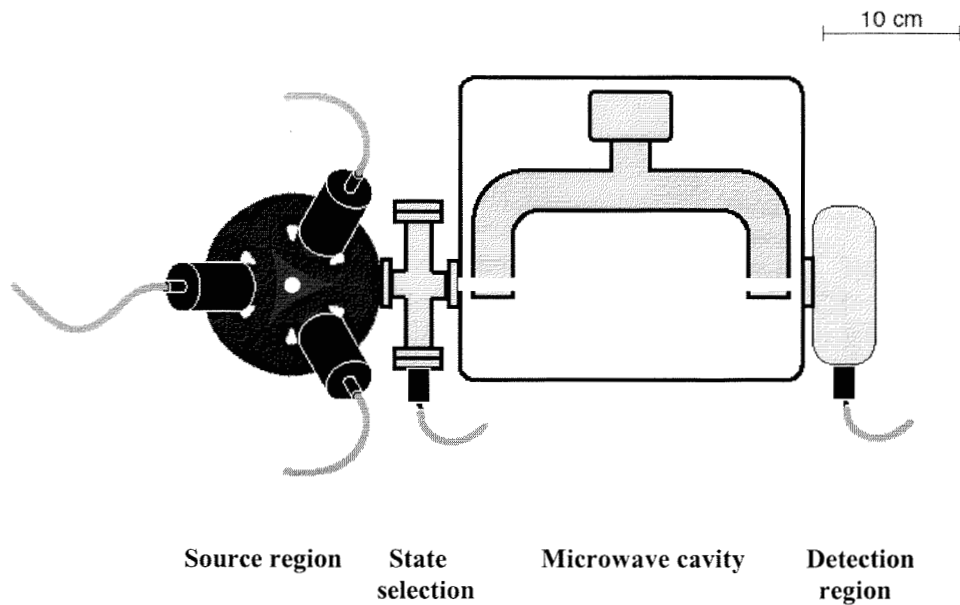
In this paper we will present an overview of the present and future of the Laser Cooling and Atomic Physics (LCAP) program in support of NASA's Microgravity Fundamental Physics program. We will address the role played by the Jet Propulsion Laboratory in developing the core technologies to support the wide variety of science that we envision will be explored by this program.

Over the past 15 years a wide variety of techniques have been developed to influence the motion of atomic gases using laser light. These techniques, termed collectively 'laser cooling', have been utilized to produce samples of atoms with temperatures less than one millionth of a degree above absolute zero. Such laser cooled samples are ideal for a wide variety of atomic physics experiments, including studies of Bose-Einstein condensation (a novel coherent state of macroscopic matter formed at low temperatures and high densities), the development of ultra-high precision atomic clocks, and the construction of atomic interferometers.

Because of the limitations imposed by gravity on terrestrial laser cooling experiments, the Fundamental Physics sub-discipline of NASA's micro-gravity research program launched a campaign in the area of Laser Cooling and Atomic Physics (LCAP), beginning with a NASA research announcement (NRA) in 1994, with a following NRA in 1996. An additional NRA will take place in November of 1999. Currently there are 12 projects funded for ground research, and two flight definition experiments, both of which are aimed at developing the next generation of ultra-precise clocks.

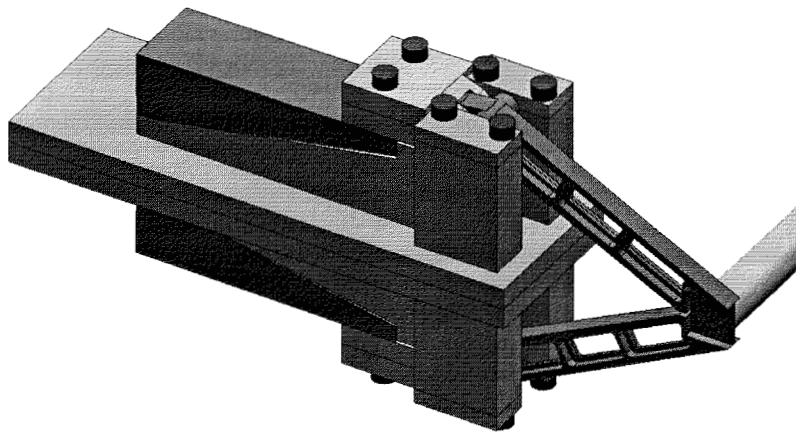
These clock experiments will rely on micro-gravity for their performance and, in addition, will utilize the difference in the gravitational potential between the earth's surface and the International Space Station to perform a variety of tests of the theory of general relativity. The first of these, the Primary Atomic Reference Clock in Space, (PARCS) has as Co-Principle Investigators Dr. Don Sullivan of the National Institute of Standards and Technology (NIST), and Professor Neil Ashby of the University of Colorado. PARCS is planned to fly aboard the space station late in 2004. The other flight experiment, the Rubidium Atomic Clock Experiment (RACE), is led by Principle Investigator Kurt Gibble, of Yale University. This experiment differs from the PARCS experiment in that it utilizes a different atomic species (rubidium as opposed to cesium) which can result in improved time accuracy.

A generic schematic of a space-based atomic clock is shown in figure 1. A cold sample of atoms is collected in the source region and then given a push so that it drifts freely along the beam tube. The atoms pass into a state selection chamber, which prepares them in a particular state, and then through a microwave interrogation chamber which induces a particular atomic transition, if the frequency of the microwaves is exactly that of the atoms. The final state of the atoms is then read out by lasers as they pass through the detection region. A more detailed discussion of space based clocks can be found in the papers by Sullivan *et al.* and Gibble *et al.* in these proceedings.



**Figure 1.** Schematic of laser-cooled space clock.

Instrument development and PI support for these and later LCAP flights is provided by the Time and Frequency Sciences and Technology Group of the Jet Propulsion Laboratory. An example of the unique technologies being developed is the novel non-magnetic shutter system shown in figure 2, which is capable of performing reliably for one year in ultra-high vacuum, without perturbing the microgravity environment. Another challenging area is the development of rugged compact laser systems, capable of producing high power single frequency laser light with the stability and frequency tunability needed to meet the demands of a laser cooling experiment. Such a device must also be capable of up to one year of stand-alone operation. Other components and subsystems are also under development to provide the same capability available in ground-based laboratories on the Space Station.



**Figure 2 .** Conceptual design of non-magnetic shutter for the PARCS and RACE missions.

A key to minimizing the overall cost of the LCAP program is to develop experiments with as much modularity and reusability as possible. Thus the laser and optics subassembly for the PARCS experiment

will also be suitable for a variety of future LCAP flights using atomic cesium. The RACE laser and optics subassembly, will have a similar design to the PARCS one, but will utilize different components in order to match the rubidium wavelength. Again, this system will be designed to be easily refurbished for future flights involving rubidium. Currently it is believed that most, if not all, LCAP flights will utilize one of these atomic species.

Amongst the exciting prospects for future flights are experiments involving BEC's, atomic lasers (sources of coherent atomic beams, which are analogous to optical lasers), searches for an electron dipole moment, and atom interferometry experiments, which will allow testing the validity of a variety of fundamental physical laws.

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